BIRLA INSTRITUTE OF TECHNOLOGY & SCIENCE, PILANI, PILANI CAMPUS
CHEMICAL ENGINEERING DEPARTMENT

Course Title: Process Design Principles - I (CHE F314)

Mid Semester Test (Closed Book)

Marks: 75 ` **Date: 11/10/17** **Time: 90 minutes**

Note: Make the suitable assumption by clearly stating them, if necessary. Write all steps clearly.

1. **(5 Marks)**
   A stream containing 500 mol/h of benzene and 50000 mol/h of air fed to absorption column. Benzene is recovered as per the heuristic by water as solvent. Water flow rate to the distillation column is 5000 mol/h. Based on the heuristic what should be the **total flow rate of distillate and bottom products**, if the desired product purity of benzene is 99%?

2. **(5 Marks)**
   Ethylene glycol ($HOCH_2CH_2OH$), used as an antifreeze, is produced by reacting ethylene oxide with water. A side reaction produces an undesirable dimer, DEG:
   $C_2H_4O + H_2O \rightarrow HOCH_2CH_2OH$
   $HOCH_2CH_2OH + C_2H_4O \rightarrow HOCH_2CH_2OCH_2CH_2OH$
   Discuss the design guidelines with respect to decision making at level-3 corresponding to the use of excess amount of reactant.

3. **(6 Marks)**
   Acetone is produced by dehydrogenation of isopropanol (IPA) as follows:
   $(CH_3)_2CHOH \rightarrow (CH_3)_2CO + H_2$
   The heat of reaction at 570^{o}F and 1 atm is 25,800 Btu/mol. Calculate the reactor heat load for producing 200 mol/h of acetone, if conversion is 0.75 and also suggest whether **the reactor is to operated adiabatically or isothermally based on reactor heat load**. **Also mention if a diluent or a heat carrier is required**.

4. **(4 Marks)**
   Consider the components and the destinations given below with their normal boiling points for a gas phase reaction. Identify the groups and the number of possible recycle streams? Provide Justification for your answer.

Component	**Boiling Point (^{o}C)**	**Destination Code**
A	111	Valuable by product
B	-161	Reactant-recycle to R2
C	253	Reactant-recycle to R1
D	-253	Reactant-recycle to R1
E	80	Reactant-recycle to R2
F	-270	Reactant-recycle to R1
G	180	By-product as fuel

5. **(5 Marks)**
   Benzene is produced from HDA process via following reactions:
   $C_6H_5CH_3 + H_2 \rightarrow C_6H_6 + CH_4$
   $2C_6H_6 \Leftrightarrow 2C_6H_5 + H_2$
   If the fresh feed of toluene is 100 mol/h. The conversion of toluene in the reactor is 60% and selectivity (moles of benzene produced/mole of toluene reacted) is 0.75. The unconverted toluene is completely recovered in the separator recycled back to the reactor. **Calculate the total feed of toluene to the reactor**.

6. **(15 Marks)**
Consider a condensation process for recovering acetone from air stream (acetone = 10.3 mol/h and air = 687 mol/h). The feed stream is available at ambient conditions (77 °F and 1 atm).
(a) Draw a flow sheet for the acetone recovery process.
(b) If the condensation process operates at 15 psia, what temperature would be required to recover 99.5% of acetone?
(c) If the condensation process operates at 100 °F, what pressure would be required to condense 99.5% of acetone?
(d) Discuss the results obtained from (b) and (c).

Vapor pressure data: Antoine equation, $\ln(p^*) = A - \frac{B}{C+T}$
where, p^* = vapor pressure in mm Hg, T = temperature in K
Acetone: A = 16.6513, B = 2940.46, C = -35.93

7. **(15 Marks)**
Ethylene is produced by the following reactions:
$C_2H_6 + 0.5O_2 \rightarrow C_2H_4 + H_2O$
$C_2H_6 + 3.5O_2 \rightarrow 2CO_2 + 3H_2O$
Develop a correlation for selectivity (S) and conversion (x) for the following data on product distribution **using method of linear least squares or method of averages**. Also calculate the optimum conversion corresponding to maximum yield.

Moles of C_2H_4 produced/mole of C_2H_6 converted	0.989	0.975	0.952	0.93	0.884	0.826	0.769
Moles of C_2H_4 produced/mole of C_2H_6 fed	0.099	0.146	0.190	0.233	0.265	0.289	0.308

8. **(20 Marks)**
Isooctane (gasoline) can be produced by the reactions:
$\text{Butene} + \text{Isobutane} \rightarrow \text{Isooctane}$
$\text{Butene} + \text{Isooctane} \rightarrow C_{12}$
The reactions take place in the liquid phase at 45 °F and 90 psia. Selectivity (S) is defined as Isooctane produced per mole of butene converted. The desired production rate is 918 mol/h. One feed stream contains 8% C_3, 80% butene, and 12% n-C_4, while the other contains 12% C_3, 73% i-C_4 (isobutane) and 15% n-C_4. **Draw the recycle structure of the flow sheet and calculate the stream flow rates (inputs, outputs, recycle flows, reactor inlet) in terms of design variables**. Assume that the impurities present in feed streams are separated after reaction and utilized as fuel.

ALL THE BEST